N79-19038

Paper No. 29

CANCELLATION OF RESIDUAL SPACECRAFT ACCELERATIONS FOR ZERO-G SPACE PHYSICS EXPERIMENTS

James B. Stephens, *Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California*

ABSTRACT

The Drop Dynamics Module houses an acoustic positioning system which counteracts the effects of small accelerations of a spacecraft and thus allows long-term study of free-floating materials such as liquid drops. The acoustic positioning system provides an acoustic "well" in the center of the experiment chamber. Data collection is by cinematographic photography. The module subsystems are discussed in this paper.

I. INTRODUCTION

The Drop Dynamics Module (DDM) is a Spacelab-compatible acoustic positioning and control system for conducting drop dynamics and physics experiments in the nearly weightless environment of space. The use of acoustics for levitating and manipulating materials counteracts perturbing effects caused by small accelerations of the spacecraft. The system consists basically of a chamber, a drop injector subsystem, an acoustic positioning subsystem, a control subsystem, and a data collection subsystem. The principal means of data collection is by cinematographic cameras. A drop of a selected liquid is positioned in the center of the chamber by forces created by acoustic standing waves. By varying the phase and amplitude of the acoustic waves, the drop can be spun or oscillated up to fission. The module is designed to perform its experiments unattended, except for startup and shutdown events and other unique events requiring the attention of the Spacelab payload specialist.

The major module subsystems are presented in the following discussion.

II. MODULE SUBSYSTEMS

Figure 1 is a functional block diagram of the module, while Figure 2 is an artist's concept of the module in place on Spacelab. The Spacelab-borne subsystems of the module include the acoustic chamber, control electronics, and imaging and data acquisition. The ground-based subsystems include the

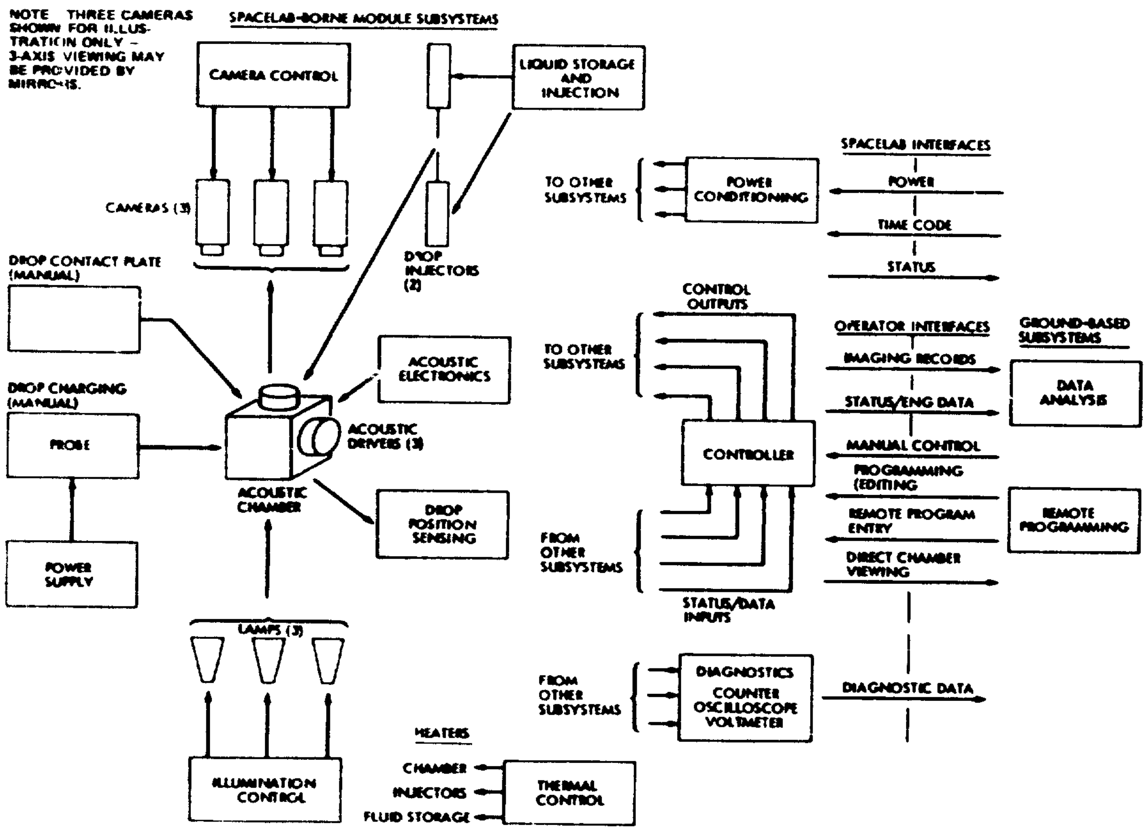

Fig. i—Drop dynamics module functional block diagram

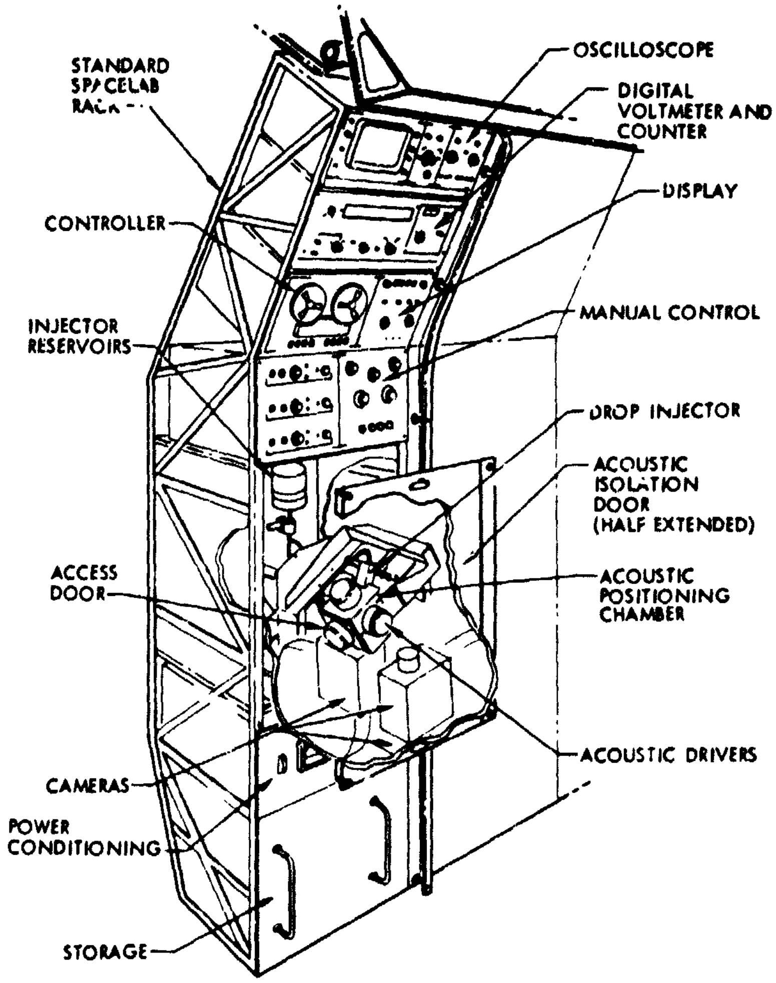

Fig. 2—Spacelab rack subsystem (possible implementation)

necessary hardware and software for generation of automatic sequence programs and for data analysis from the imaging and other data records.

A. Acoustic Chamber

The acoustic chamber is center stage for the experiment activities: it is the resonant cavity which provides the necessary acoustic standing waves to position liquid drops and it is the backdrop for viewing and imaging the drop action.

The chamber is a thick-walled (1.27 cm) lucite rectangular parallelepiped unit (i.d. approximately 15.2 x 15.2 x 16.9 cm). At the center of the chamber the imaging clear field of view is 12 x 12 cm. Acoustic driver ports are located on three orthogonal walls; the other three walls are transparent for imaging and viewing, and one of these is hinged for access to the chamber interior. Injector ports at the center of two opposite corners provide for introduction of the liquid drop.

A separate frame acts as a mount structure for the cameras, mirrors, lights, sensors, injecters, and acoustic drivers. This chamber frame is mounted on retractable support slides to provide access for adjustment and servicing.

The chamber mockup is shown in Figure 3, as it will be used in zero-g aboard KC-135 aircraft.

B. Acoustic Positioning

The DDM will provide sufficient acoustic forces to initially position and maintain the center of a 2.5 cm drop within 3.0 cm of the center of the chamber during module accelerations up to 10^{-2}g. For a 2.5-cm diameter drop of water, this force will be approximately 80 dynes. At 300°K and 1 atm, the acoustic resonant frequencies of these drivers will be 1141, 1141, and 1027 Hz. The acoustic forces will be controlled so that the drop centers (as defined above) within 1.0 minute after injection.

The acoustic power level, relative phase, modulation frequency, modulation amplitude and modulation phase are controlled independently for each axis.

Introduction of phase shift will cause the X-Y signal to rotate about the "Z", or long axis of the chamber, while the torque is controlled by varying either the amplitude or phase. The nominal maximum drop rotation rate will be 12 rad/sec for a 2.5-cm drop, with a controllable angular acceleration of up to 1.0 rad/sec^2. The minimum rate of change of acceleration will be 0.01 rad/sec^3, and the minimum rise time for the torque on the drop will be 0.1 sec. For a 2.5-cm diameter water drop,

ORIGINAL PAGE IS
OF POOR QUALITY

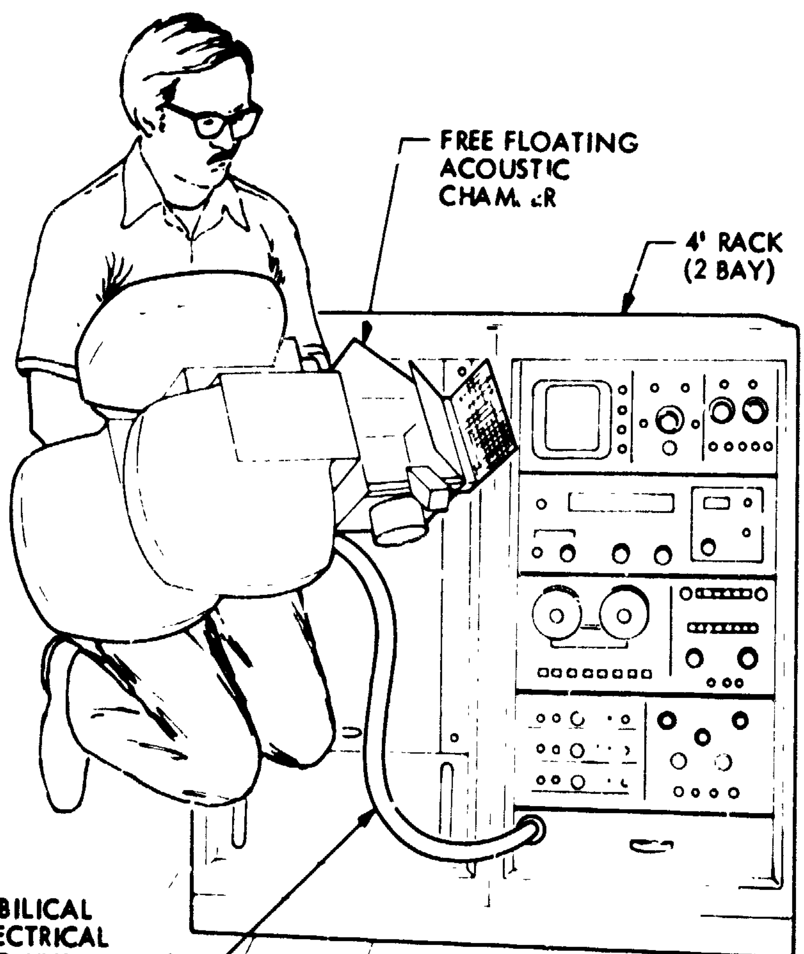

Fig. 3—KC-135 rack subsystem (possible implementation)

C-5

the maximum acceleration of 1.0 rad/sec^2 will correspond to a torque of 5.1 dyne-cm.

Modulation of the acoustic signal amplitude alone will cause an oscillation force to be applied to the drop in any or all of the three chamber axes. The nominal drop oscillation stimulus frequencies will be in the range of 0 to 100 Hz, with controllable increase or decrease at a maximum rate of change of 1 Hz/sec. The oscillation signal (acoustic amplitude modulation) will be available in three phases: 0°, 90°, and 180°. The phase of the Z-axis modulation will be fixed. The X and Y axes may each be modulated with either the 0°, 90°, or 180° signal.

In addition, removal of the acoustic power will allow the drop to drift undisturbed within the chamber. A drop centering system will maintain the drop within the imaging field of view and prevent collision with the chamber walls by using optical sensors to control the acoustic power level.

The power levels, sensor location and other parameters of the drop centering system will be selected to prevent the drop from contacting the chamber wall in the presence of a 10^{-2}g acceleration. The centering forces will be limited to assure that the drop does not fission unintentionally within the imaging field of view even if this results in a collision with the chamber wall.

C. Fluid Management

Apart from acoustically manipulating the drop within the chamber, provisions have been made for storing, injecting, and charging the fluids.

The main function of the injector subsystem is to place a drop (up to 10 cm^3) at the center of the chamber with as little residual motion as possible, at a rate of 0.1 - 1.0 cm^3/sec. After injection, the residual drop velocity is 0.5 cm/sec or less. The subsystem can accommodate any nonflammable, non-toxic, reasonably chemically inert liquid which has a vapor pressure of less than one atmosphere at the maximum module operating temperature (55°C). The subsystem will be capable of multiple injections and retrievals of liquid drops

Six different reservoirs of liquid will be provided. Each reservoir will have two flexible plastic tubes (tygon) attached, each with an attached probe (the probes resemble long blunt hypodermic needles). The tips of the injectors will be changed every time the liquid is changed. The injecter mechanisms drive the probes into the center of the chamber where the liquid is released. Once the drop is formed, the probes are abruptly withdrawn from the chamber, leaving the drop in the center.

After injection the drop may be electrically charged or discharged by inserting the charging probe so that it penetrates the drop. The voltage can be manually adjusted, the drop charged, and the probe withdrawn.

The drop may be electrostatically charged to ±1000 volts. The drop charging voltage will be controllable to ±1V up to 100V, and ±5V up to 1000V. The charging mechanism will also be capable of discharging the drop to within 10V of the chamber wall potential. Provision will be made for maintaining the entire interior surface of the chamber at module ground potential during charged drop experiments. This will require the chamber interior to be coated with a conductive material, so that the entire surface is one conducting surface.

D. Viewing and Imaging

The chamber interior can be viewed directly by the operator through the transparent walls. With the chamber in its normal operating position, the entire chamber interior is visible. The direct viewing provision will allow the module operator to operate module controls comfortably while viewing the chamber interior.

For direct viewing, the DDM will provide steady (non-pulsed) illumination of the chamber interior. The intensity and direction of illumination will be sufficient so that a clear (undyed) water drop may be clearly seen against the chamber background, with an apparent drop brightness of at least 200 ft-Lamberts.

The principal means of data collection during the experiments is by three 16 mm cinematographic cameras mounted on three mutually orthogonal sites of the acoustic chamber. Included in the field of view of each camera is an alphanumeric film annotation display and a reseau pattern or grid for geometric calibration of the cameras to an accuracy of 0.02 cm. One camera images the chamber center directly, while the other two image it via mirrors.

The cameras will have a focal length of 25 mm, aperture of f/8, and depth of field 16.09 cm for two views and 17.78 cm for the third view. Practically any high-speed color or black-and-white film is usable.

Imaging will be accomplished so that the size and shape of the drop may be determined to ±0.02 cm. The minimum resolution in the object plane will be 20 cycles/cm (line pair/cm)(When using color film, the imaging resolution requirements are reduced.) Images will be recorded at rates up to 200 per second for each of the three views.

The imaging sample rate (frame rate) will be stable to within ± 0.1 frame/sec, and the images of each of the three axes will be synchronized to within ± 0.0005 sec of each other and of the module clock.

The illumination subsystem utilizes three strobe lights which are mounted around the acoustic driver ports to illuminate the drop from any of the three orthographic sides opposite the camera imaging ports; i.e., the drop can be front, back or side lit. The light can be diffused or filtered by a coating applied to the chamber wall as desired.

E. Control and Sequencing

The module may be controlled manually by the operator, completely automatically, or in some combination of these modes.

The module basic control functions will be controlled through software programs generated either by the DDM or at remote locations (away from the module). To facilitate remote programming, the program language and memory medium will be compatible with commonly used general purpose computers. The program memory will be non-volatile for the expected duration of a Spacelab mission.

The DDM will provide subroutine capability for programming short, frequently used sequences. Typical sequences which could be stored in subroutines will include the basic rotation and oscillation experiment sequences described in Ref. 1. There will be no limit on the size and number of subroutines other than that imposed by total controller memory capacity. The purpose of the subroutines will be to simplify programming and to allow manual commanding of simple operations. Subroutines will be stored in read-only memories (ROMS) or similar storage media. Subroutines may be accessed either manually or under software control.

F. Data Analysis

The ground-based portion of the DDM will provide support for the reduction and analysis of DDM imaging records and engineering and status data records. The objective of the data analysis will be to convert raw DDM data to a form usable by the science users. Prior to analysis of imaging records, high-quality copies will be made for storage and distribution to users. In general, data analysis will consist of:

1) Formatting and tabulating all module engineering and status data and correlating it to the imaging records

2) Mathematical characterization of drop profiles as a function of time, acoustic power, phase, and modulation frequency

3. Derivation from (2) of drop oscillation resonant frequencies (particularly the fundamental), rotation rates, damping constants, drop radii, and line shapes.

The imaging records will be analyzed by digitizing the coordinates of at least 32 points on the drop profile for a selected set of images (see Ref. 1). In addition the location of tracer particles, if any, will be digitized.

The digitizing of imaging records may be accomplished manually with the assistance of a light table, or automatically. The digital imaging records will be on magnetic tape in a format compatible with standard general-purpose computers.

The DDM will provide software for analysis of the module data records and the digitized imaging records. This software will be written in a commonly used language (such as Fortran).

III. CONCLUSIONS

The design of the module meets the requirements of the baseline experiment proposed by JPL; however, modifications may be made as needed to accommodate other experiments, providing funding is available. The baseline experiments on rotation and oscillation of liquid drops are precursors to future experiments in which the oscillation of rotating drops will be studied. The experiments are also precursors to ones in which the drops are electrically charged, electrically conducting, dielectric, non-Newtonian, or superfluid; and where external fields are applied (electric, magnetic, electromagnetic, acoustic, or thermal). In addition, it is envisaged that multiple drop experiments will be performed in which the interactions of free drops can be observed. These and other studies in basic physics will be greatly aided by the capabilities of the Drop Dynamics Module.

REFERENCES

1. Wang, T. G., Elleman, D. D., and Saffren, M. M., <u>JPL Drop Dynamics Experiment</u>, JPL Document 701-224, 30 July 1975.

2. <u>Drop Dynamics Module Project Plan</u>, JPL Document 701-221, 16 July 1976.

Paper No. 30

UNIQUE TEST FACILITY FOR EVALUATION OF MHD ELECTRODE AND INSULATOR MATERIALS

I. M. Grinberg, R. G. Luce, and A. A. Boiarski, *Battelle's Columbus Laboratories, Columbus, Ohio*

ABSTRACT

The development of central-station, open-cycle, coal-fired MHD power generators depends to a great extent on the ability of the critical electrode and insulator components to perform satisfactorily. The unique performance requirements for the materials must be considered in terms of the long-duration physical, thermal, chemical, and electrical environments in which reliable generator operation must be maintained. Development of electrode and insulator materials requires their evaluation in an environment that closely simulates expected central-station channel operational conditions in order to adequately relate the effects of long-time material exposure with those of high-temperature, seed, coal-slag, and electrical current transfer on critical material properties. Such screening evaluations are difficult to conduct economically under well-characterized controlled conditions in an operational MHD generator. This paper describes a unique MHD test facility which is capable of providing a simulated MHD environment over a broad range of gas temperature, pressure, fuel, electric field, and combustion gas conditions and is well suited for the conduct of materials evaluations.

The test facility utilizes a hybrid electric arc-heated combustion-driven gas supply. The use of electric arc-heated gas in conjunction with combustion-driven flow is shown to provide the flexibility required to independently assess relative effects of the important gas side properties on material performance. It is also shown that the important MHD channel parameters can be independently controlled without application of a magnetic field with application of an applied voltage to provide the desired current density in electrode materials.

PAGE BLANK NOT FILMED

A brief description of each of the components and operational envelope of the overall system is given in terms of the attainable simulated test channel conditions. Conditions achieved in tests recently conducted to evaluate electrode materials used in the U02 MHD facility are shown. Also included is a brief description of diagnostics used to characterize the gas environment.